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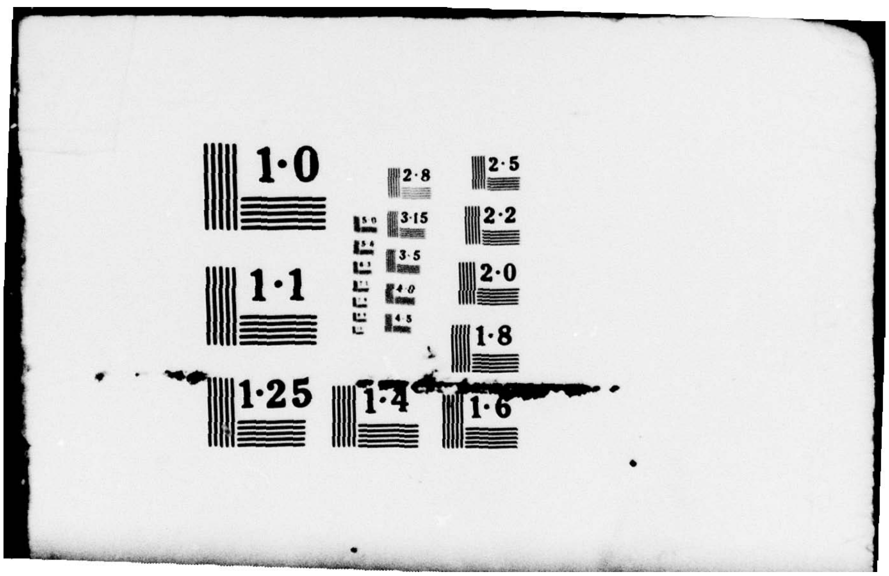
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OBSERVING PREFERENCES FOR EDUCATIONAL QUALITY: THE WEAK COMPLEMENTARITY APPROACH

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This paper applies the weak complementarity approach to the problem of estimating the demand for school quality and other local public goods. Using the same data used by Oates (1969) in his classic study, a demand function for housing is estimated, from which the efficient relative levels of public goods provision are computed. The statistical problems involved in estimating a housing demand function from cross-section data are discussed.

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OBSERVING PREFERENCES FOR EDUCATIONAL QUALITY: THE WEAK COMPLEMENTARITY APPROACH*

1. Introduction

Paul Samuelson's scepticism about the prospects for obtaining information about the demand for public goods has helped to stimulate a considerable amount of research aimed at overcoming the difficulties he identified (Samuelson, 1954, 1969). Indeed, this special issue of the Journal is illustrative of this development. In this paper, we exploit the interdependence of the demands for a local public good, educational quality, and a private good, housing, in order to calculate a relative level of educational quality consistent with Samuelsonian efficiency conditions. Using this interdependency, which Mäler (1974) has referred to as "weak complementarity," we thus are able to derive normative conclusions concerning the efficient level of educational quality for a community. We also consider the efficient provision of other local public goods.

In an important paper exploring implications of the Tiebout hypothesis, Oates (1969) estimated a hedonic price relationship between housing prices and a variety of private and public characteristics for 53 residential communities in New Jersey, all of which are in metropolitan New York. In an informal discussion, he suggested the possibility of using this relationship to determine whether public services were being provided at efficient levels by local governments (1969, pp. 966-967). We use the

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* We are grateful to Wallace Oates for his generosity in making available the data used in this paper.

Oates data here to explore this issue more formally, and to illustrate the efficacy of the weak complementarity approach.

The use of the weak complementarity method requires, in this analysis, an interdependence in the demands for housing and local public goods, the existence of a price for housing at which the marginal rate of substitution of income for each local public good is zero, and the constancy of the marginal utility of income with respect to housing prices and the provision of local public goods. While the weak complementarity approach normally assumes that consumers regard levels of public goods as parameters, it can also be used with the assumption that these levels may be choice variables. This generalization requires only that we assume that individuals select the optimal level of a private characteristic, which is in this case housing. By allowing the possibility that local public goods are either choice variables or parameters, we avoid the problem of specifying the nature of market equilibrium. A general theoretical treatment of the weak complementarity approach is provided in Bradford and Hildebrandt (1977).

In Part 2 of this paper we develop the weak complementarity approach in a spatial context and show that the marginal valuation of a consumer for public goods such as school quality can be computed by taking the derivative of the integral of the demand function for housing over prices ranging from the existing price to the price at which public goods are valueless at the margin. We present the empirical analysis in Part 3. In that section, we deal with several important statistical issues, including whether the demand relationship for housing can be identified (see Epple, Zelenitz, and Visscher, 1978), the possible heteroscedasticity of the demand function, and the separability of the hedonic price function for housing so that price per room can be computed. After claiming the successful resolution of these questions, we present normative implications for the levels of public goods provision. Brief concluding remarks are presented in Part 4.

2. Weak Complementarity in a Spatial Context

We assume that characteristics $(R, \underset{\sim}{X}, \underset{\sim}{Q})$ are embodied in each consumer's residence, where R is the number of rooms in the dwelling, $\underset{\sim}{X}$ is a vector of other private characteristics such as the age of the dwelling and its distance from a central business district, and $\underset{\sim}{Q}$ contains public characteristics including educational quality and the provision of other local public goods.[1] The value of each residence will depend on these embodied characteristics as given by a hedonic price function $H(R, \underset{\sim}{X}, \underset{\sim}{Q})$.[2]

Each consumer maximizes the value of a preference indicator subject to a budget constraint, and may be viewed as being in either a long run or a short run optimization position. In the long run, the consumer selects all components of the vector $(R, \underset{\sim}{X}, \underset{\sim}{Q})$ and the consumption level of all other goods, denoted here by W, a numeraire with a price of unity. If, however, the consumer is in a short run optimization position, then certain of the characteristics will be parameters rather than choice variables. In either optimization position, the consumer faces the following budget constraint:

$$(1) \quad \frac{H(R, \underset{\sim}{X}, \underset{\sim}{Q})}{d} + TH(R, \underset{\sim}{X}, \underset{\sim}{Q}) + W = M,$$

where d is a discount factor which converts the value of a dwelling to a periodic cost, T is the effective property tax rate (T thus reflects the property tax rate and the assessment ratio used in assessing the value of the residence for tax purposes), and M is money income.

We assume that the hedonic price function is separable and of the form:

$$(2) \quad H(R, \underset{\sim}{X}, \underset{\sim}{Q}) = RJ(\underset{\sim}{X}, \underset{\sim}{Q}),$$

where J is the value per room of a residence. This separability assumption cannot be justified a priori; the validity of this assumption is, however, supported if the hedonic price function is a multiple of the number of rooms as in (2). We show below that this is the case in the problem at hand.

The gross price per room for a time period is thus given by:

$$(3) \quad P(\underset{\sim}{X}, \underset{\sim}{Q}) = \frac{J(\underset{\sim}{X}, \underset{\sim}{Q})}{d} + TJ(\underset{\sim}{X}, \underset{\sim}{Q}).$$

The gross price per room as given in (3) thus incorporates the discount factor and periodic tax payments. Given (3), the budget constraint (1) can be rewritten as:

$$(4) \quad RP(\underset{\sim}{X}, \underset{\sim}{Q}) + W = M.$$

We now define an indirect utility function V which is conditional upon the public characteristics $\underset{\sim}{Q}$; the private characteristics R, $\underset{\sim}{X}$, and the numeraire W are assumed to have been selected optimally by the consumer. Our assumption that the marginal utility of income is constant with respect to the price per room P and the public characteristics $\underset{\sim}{Q}$ suggests that we can write this indirect utility function in the following form: [3]

$$(5) \quad V = \frac{M^{(1-\delta)}}{(1-\delta)} + f(P(\underset{\sim}{X}, \underset{\sim}{Q}), \underset{\sim}{Q}).$$

Note that (5) is applicable for any $\underset{\sim}{Q}$, whether or not these characteristics have been selected optimally. Further, it applies to (P, $\underset{\sim}{Q}$) combinations that might not be consistent with $P(\underset{\sim}{X}, \underset{\sim}{Q})$. To emphasize this point, we will delete the arguments of P in the remainder of the analysis.

We seek to obtain the consumer's marginal evaluation of one member of $\underset{\sim}{Q}$, educational quality, which we designate as Q_1. For any P, the marginal rate of substitution of money income for Q_1 is given by:[4]

$$(6)\quad \frac{V_{Q_1}}{V_M} = M^{\delta} f_{Q_1}(P, \underset{\sim}{Q}),$$

which can be rewritten as:

$$(7)\quad \frac{V_{Q_1}}{V_M} = M^{\delta} f_{Q_1}(\overline{P}, \underset{\sim}{Q}) + \int_{\overline{P}}^{P} \left[\partial (V_{Q_1}/V_M)/\partial \xi\right] d\xi ,$$

where $\overline{P}$ is an arbitrary price per room. Note that the functional form of the utility function (5) implies $\partial(V_{Q_1}/V_M)/\partial P = \partial(V_P/V_M)/\partial Q_1$. This is true because:

$$(8)\quad \frac{V_P}{V_M} = M^{\delta} f_P(P, \underset{\sim}{Q}) ,$$

and $f_{PQ_1} = f_{Q_1 P}$ by Young's Theorem.

We now assume that there exists a price for housing so high that Q_1 is valueless at the margin. This price might, for example, exhaust such a high fraction of money income that a consumer will not exchange M for Q_1. Let this price be $\overline{P}$, so that (7) becomes:

$$(9)\quad \frac{V_{Q_1}}{V_M} = \int_{\overline{P}}^{P} \left[\partial(V_P/V_M)/\partial Q_1\right] d\xi .$$

Using Roy's Identity, the demand for rooms, R^*, can be written:

$$(10)\quad R^* = -V_P/V_M = -M^{\delta} f_P(P, \underset{\sim}{Q}) \equiv M^{\delta} g(P, \underset{\sim}{Q}).^5$$

The marginal rule of substitution of money income for Q_1, evaluated at $(M, P, \underset{\sim}{Q})$, can be written:

$$(11)\quad \frac{V_{Q_1}}{V_M} = M^{\delta} \int_{P}^{\overline{P}} g_{Q_1}(\xi, \underset{\sim}{Q})d\xi.$$

The marginal valuation of Q_1 can thus be obtained by computing the derivative of the integral of the demand function for number of rooms, R. The possibility that Q_1 and P might enter the demand functions of other goods need not concern us; we require only that the assumptions above be met. A further difficulty, of course, is presented by our inability to observe $\overline{P}$. Happily, this turns out to be no problem in the computation of the optimum level of Q_1 in terms of other private characteristics.

3. Empirical Application

The indirect utility functions of individual consumers who reside in a particular area will be parameterized by the variable $\theta_i = \beta\varepsilon_i$, where β is the average value of the parameters, and ε_i accounts for deviations of the i^{th} consumer. The parameter θ_i is assumed to be multiplicative with the function f of the indirect utility function specified in (5). Thus, under the specified parameterization, the demand function of the i^{th} consumer for rooms can be written:

$$(12)\quad R_i^{*} = M_i^{\delta} g(P, \underset{\sim}{Q})\beta\varepsilon_i.$$

Note that we are continuing to suppress the arguments for P.

Taking the log of this demand function (12), and utilizing a first order approximation in the logs of g, we have:[6]

$$(13)\quad \ell n R_i^{*} = \ell n\beta + \delta\ell nM_i + \alpha_0\ell nP + \alpha_1\ell nQ_1 + \ldots + \alpha_k\ell nQ_k + \ell n\varepsilon_i,$$

assuming k characteristics in Q. We assume that the distribution of ε_i is log-normal, so that $\ln\epsilon_i$ is normally distributed with $E(\ln\epsilon_i) = 0$.

The data used by Oates (1969) were employed in this study. These data are taken primarily from 1960 observations in New Jersey.[7] The data include observations for what might be regarded as the "median" household in each community: median number of rooms (R), median family income (M), and the median value of owner-occupied dwellings.[8] Observed public characteristics include school quality (S, measured as expenditure per pupil), other local public goods (N, measured as public non-school spending per capita), and an environmental variable (C, measured as the value of commercial/industrial property per capita).[9]

An ordinary least squares regression yielded the following result, with t statistics given below in parentheses:

$$(14) \quad \ln\hat{R} = \underset{(-3.34)}{-1.178} + \underset{(10.91)}{.470}\ln M - \underset{(-5.84)}{.404}\ln P + \underset{(3.14)}{.175}\ln S + \underset{(5.75)}{.144}\ln N - \underset{(-2.36)}{.027}\ln C$$

$$R^2 = .851.$$

Note that other private characteristics, including age of dwelling and distance from a central business district, are determined in their own demand relationships; neither these nor other private characteristics were significant when included in the regression.[10]

While the relationship estimated has properties that are remarkable for cross section data, there are several statistical issues that must be addressed. These include the use of ordinary least squares, whether the demand function can be identified, heteroscedasticity, and separability. We discuss these in turn.

In our theoretical model, we set aside the problem of distinguishing between short run and long run equilibria by allowing the public characteristics (S, N, and C in this case) to be <u>either</u> choice variables or parameters. If they are choice variables, however, then they would be correlated with the error term $\ell n\varepsilon_1$ in (13). Rather than making the choice variable assumption and using two-stage least squares, we prefer to allow both possibilities. In addition to the defense of greater generality for this procedure, we feel that the ordinary least squares approach can be justified for its minimum variance property (Goldberger, 1963, pp. 359-360).

The second, and perhaps most worrisome, issue is identifiability. However, it is likely that the hedonic price function $H(R, \underset{\sim}{X}, \underset{\sim}{Q})$ depends on variables which do not enter the utility functions or budget constraints of consumers. These might include population density, population, and population change. Even if consumers regard these variables as important indicators of, say, quality of life, the demand relationship may still be identifiable. Suppose, for example, that individuals are concerned about community population size. It seems reasonable to assume that individuals will differ in their assessments of this variable; a change in population may increase the demands of some consumers for number of rooms and decrease it for others. Thus, even if population size (or change in population size) does enter the utility functions of some consumers, it may cancel out of the aggregate demand function or, in the case here, the demand function of the "average" median consumer. Further, because a change in a variable like population size will tend to create a long run disequilibrium condition, and is not directly part of the consumer's choice problem in the short run, it will contribute to the identification of (13).

The third statistical problem in our analysis is heteroscedasticity. One can assume that $Var(\ell n\varepsilon_i) = \sigma^2$, and is thus invariant across individuals. A random sample of observations would then generate a homoscedastic error term. However, only observations of the "median" household in each community were used in estimating (13). This creates a problem, because if $\ell n\varepsilon_i$ is distributed normally, then the variance of the median is $\sigma_{md}{}^2 = \pi\sigma^2/2A_j$, where A_j is the number of residences in the community from which the median was drawn. The appropriate transformation to deal with this heteroscedasticity would be to multiply each term in (13) by $\sqrt{A_j}$ and then to estimate the transformed model using ordinary least squares. However, such a model would be difficult to interpret. It is our view that an estimated relationship should lend itself to economic interpretation. Further, an examination of the residuals in (14) did not suggest the presence of a heteroscedasticity problem.

Finally, there is the problem discussed above of the separability of the hedonic price function, i.e., whether $H(R, \underset{\sim}{X}, \underset{\sim}{Q})$ can be written as $RJ(\underset{\sim}{X}, \underset{\sim}{Q})$. Our estimate of the hedonic price function yielded:

$$(15)\quad \underset{}{\ell n\hat{H}} = \underset{(-2.78)}{-1.391} + \underset{(5.99)}{1.012\ell nR} + \underset{(3.38)}{.347\ell nS} + \underset{(2.50)}{.158\ell nN} - \underset{(-4.28)}{.106\ell nD}$$

$$+ \underset{(5.20)}{.116\ell nA} - \underset{(-2.71)}{.196\ell nT} - \underset{(-.77)}{.017\ell nK} - \underset{(-.66)}{.015\ell nC},$$

$$R^2 = .855,$$

where H is the median value of owner-occupied dwellings, D is distance from mid-town Manhattan, A is the percentage of dwellings built since 1950, T is the effective tax rate, and K is the population density. R, S, N, and C are the same variables used in (14). The coefficient for ℓnR is 1.052 (t = 6.70) when one deletes K and C and estimates (15). The assumption of separability thus seems to be a reasonable approximation.

It is our view that the use of ordinary least squares to estimate (14) is appropriate for the economic issue we are addressing. The statistical properties of (14) permit the derivation of normative conclusions concerning the levels of public goods provision in the Oates sample of communities. We utilize (14) in (11) to solve for the marginal rates of substitution of money income M for school quality (S), non-school public goods provision (N), and environmental quality (C). We obtain:

$$\text{(16a)} \quad V_S/V_M = .0902M^{.470}S^{-.825}N^{.144}C^{-.027}\left[\bar{P}^{.596} - P^{.596}\right]$$

$$\text{(16b)} \quad V_N/V_M = .0742M^{.470}S^{.175}N^{-.866}C^{-.027}\left[\bar{P}^{.596} - P^{.596}\right]$$

$$\text{(16c)} \quad V_C/V_M = -.0139M^{.470}S^{.175}N^{.144}C^{-1.027}\left[\bar{P}^{.596} - P^{.596}\right] .$$

Because $\bar{P}$, the price of rooms at which the public good is valueless, is almost certainly outside the range of observations available, its presence in (16) poses a difficulty. It is not, however, an intractable one.

We assume that the median household's marginal rate of substitution is equal to the average. Then the sum of marginal rates of substitution is found by multiplying the median household's rate times the number of residences in the community; the efficient provision of the good requires that this sum be equal to the marginal cost of providing the public good. We can use this relationship for any two of the public goods to eliminate

$\overline{P}$ and solve for the level of one of the public goods in terms of the other. Note that the marginal cost of S is equal to the number of pupils in public schools in the community, B_j; and the marginal cost of N is equal to the community's population, G_j. Using (16a) and (16b), when the Samuelsonian efficiency conditions are satisfied:[11]

$$(17) \quad N_j^* = .8226 \frac{B_j}{G_j} S_j^*.$$

For a specified community in which B and G are known, we can thus calculate the optimal relationship between N and S. Then the optimal levels of S and N, consistent with total community expenditures E, can be computed. Expenditures are given by:

$$(18) \quad B_j S_j + G_j N_j = E_j.$$[12]

Using (17) with (18) we get:

$$(19a) \quad S_j^* = \frac{.5486\, E_j}{B_j}$$

$$(19b) \quad N_j^* = \frac{.4514\, E_j}{G_j}.$$

To illustrate the use of these relationships, we consider the community of Glen Rock, New Jersey, in which 94% of the dwellings were owner occupied in 1960. The following data are applicable to this community:[13]

Table 1

Glen Rock, New Jersey

Median value of owner-occupied dwellings (H)	$22,600
Effective property tax rate (T)	.02669
Annual gross price per room (P)	$300.00
Median number of rooms (R)	6.4
Median family income (M)	$11,260
Expenditure per pupil (S)	$543
Non-school public spending per capita (N)	$44
Value of commercial/industrial property per capita (C)	$799
Number of owner-occupied dwellings (A)	3,331
Population (G)	12,900
Number of students enrolled in public schools (B)	2,812

Expenditures (E) in Glen Rock in 1960 were $2,094,516. Given this E, our estimate of the efficient level of expenditures per pupil is $408; the efficient level of non-school public spending per capita is $73 (the actual expenditures were $543 and $44 respectively). Because we do not have an estimate of the marginal cost of changing the amount of commercial and industrial property, we have not attempted to estimate the efficient relationship between C and S or N.

4. Conclusion

The weak complementarity approach appears to be an extremely promising one for estimating the efficient levels of public goods provision. Even in the case of housing demand and local public goods, in which we are not able to estimate the price, $\overline{P}$, at which public goods are valueless, we can estimate the correct fractions of a given level of total expenditures that should be devoted to each public good. Further theoretical and empirical work may yield methods of estimating $\overline{P}$, thus greatly increasing the power of the analysis.

The problem of identification is also one which we feel deserves continuing attention. We think that our demand function (13) is identifiable, but more empirical work is needed on the respective roles of variables in the hedonic price function and the demand function. It should be noted that the issue we have confronted is one facing all cross section analyses of demand.

The notion that consumers will, all other things equal, increase their demand for housing in response to an increase in the provision of local public goods is a compelling one. The ability to exploit this relationship in order to obtain reasonably precise estimates of the efficient levels of provision of these goods should prove to be an important policy tool.

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Footnotes

1. The symbol ~ is utilized to designate vector valued variables.
2. For a discussion of the properties of hedonic price functions, see Rosen (1974).
3. Starting with a direct utility function of the general form $U(W, R, \tilde{X}, \tilde{Q})$, we utilize the assumption that W, R, and $\tilde{X}$ are selected optimally to write the indirect utility function as $U(M - P(\tilde{X}, \tilde{Q})R, R(P(\tilde{X}, \tilde{Q}), M), \tilde{X}(P(\tilde{X}, \tilde{Q}), M))$. The assumption that the marginal utility of income is constant with respect to P and $\tilde{Q}$ implies that this indirect utility function must be of the form $V = g(M) + f(P(\tilde{X}, \tilde{Q}), \tilde{Q})$. We utilize a special case of this separable function, in which $g(M) = M^{(1 - \delta)}/(1 - \delta)$.
4. The symbol $f_{Q_1}(P, \tilde{Q})$ is the partial derivative of f with respect to the public characteristic Q_1. Although P is a function of X and $\tilde{Q}$, the indirect utility function (5) applies for any $(P, \tilde{Q})$ combination; it is mathematically permissable to hold P constant while varying Q_1.
5. Note that for the demand function (10), the income elasticity of demand is constant, $\frac{dR^*}{dM} \cdot \frac{M}{R^*} = \delta$.
6. Taking the log of both sides of (12), we get $\ell nR_i{}^* = \delta \ell nM_i + \ell ng + \ell n\beta + \ell n\varepsilon_i$. Now, $\ell ng(P, \tilde{Q})$ can be rewritten as $\ell ng(\exp \ell nP, \exp \ell n\tilde{Q})$. Utilizing a first-order approximation about ℓnP and $\ell n\tilde{Q}$ equal zero, and entering the remaining terms, we get (13).
7. See Oates (1969) for a discussion of the data base.
8. The household with the median number of rooms in a community may not, of course, be the household with the median family income. It is, however, a reasonable approximation to think of "the" median household for each community.

9. One would, of course, like better measures than these. It is unlikely, for example, that "expenditures per pupil" is a good measure of school quality. It is not, however, obvious that other possible measures (e.g., test scores, income levels of graduates) would be better, particularly in light of the wide range of roles that schools play in society.

10. We have not corrected the R^2 for degrees of freedom because it is our view that the proportion of variation explained by the regression is a more meaningful statistic. Also, the Durbin-Watson statistic is not presented because serial correlation is not a relevant issue in cross-sectional analysis.

11. Our estimate of the demand relationship is for homeowners only, and thus does not apply to communities with renters. Applying the analysis to communities with renters would require either that information about renters be included in the estimate of the demand function.

12. If a change in E were achieved by changing the property tax, then the effective property tax rate and, in turn, the gross price per room might vary. Such a price effect might influence the results given in (15).

13. See Oates (1969, pp. 969-970) for sources of this data.

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